Epitaxial growth of Weyl semimetal TaAs on GaAs (001)

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Three dimensional topological semimetals (TSMs) were experimentally discovered in the past decade and exhibit extraordinary properties such as extremely high mobility [1], conductivity [2] and magnetoresistance [3] stemming from their protected bandstructure. They are now emerging as excellent candidates for a wide variety of applications including photovoltaics [4], spintronics [5], thermoelectrics [6], and catalysts [7]. Weyl semimetals in particular have unique bandstructures with a singly degenerate linear band crossings. While there has been a great deal of success studying novel bulk single crystal TSMs, they are not suitable for device applications. Instead, epitaxial thin films are needed to access unique behaviors such as the Chiral anomaly and also insert them into more conventional device structures. Thus, there is a need to develop thin film TSMs compatible with semiconductor manufacturing to accelerate the adoption of TSMs into device applications.

We report epitaxial growth of the Weyl semimetal TaAs on GaAs(001) substrates using molecular beam epitaxy. TaAs has been widely studied in bulk crystal form but has not previously been synthesized as a single crystal film, likely due to the challenge posed by a lack of lattice matched substrates. In this presentation we discuss growth strategies to realize single crystal films and eliminate secondary phases. Fig. 1 shows x-ray diffraction and reflection high energy electron diffraction (RHEED) measurements demonstrating that the TaAs is single crystal. We will also discuss the impact of epitaxial growth on intrinsic doping and magnetoresistance.

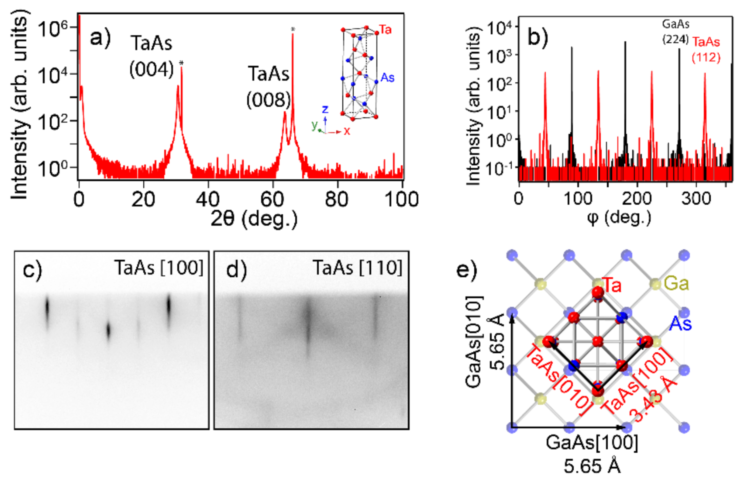

Figure 1. a) X-ray θ-2θ scan of TaAs(001)/GaAs(001), * indicate substrate peaks. b) X-ray φ scan of the GaAs(224) peak and TaAs(112) peak showing that TaAs is rotated 45 deg in plane relative to GaAs. c-d) RHEED images. E) Schematic of the orientation of TaAs/GaAs illustrating the large 14% mismatch.

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Supplementary Information

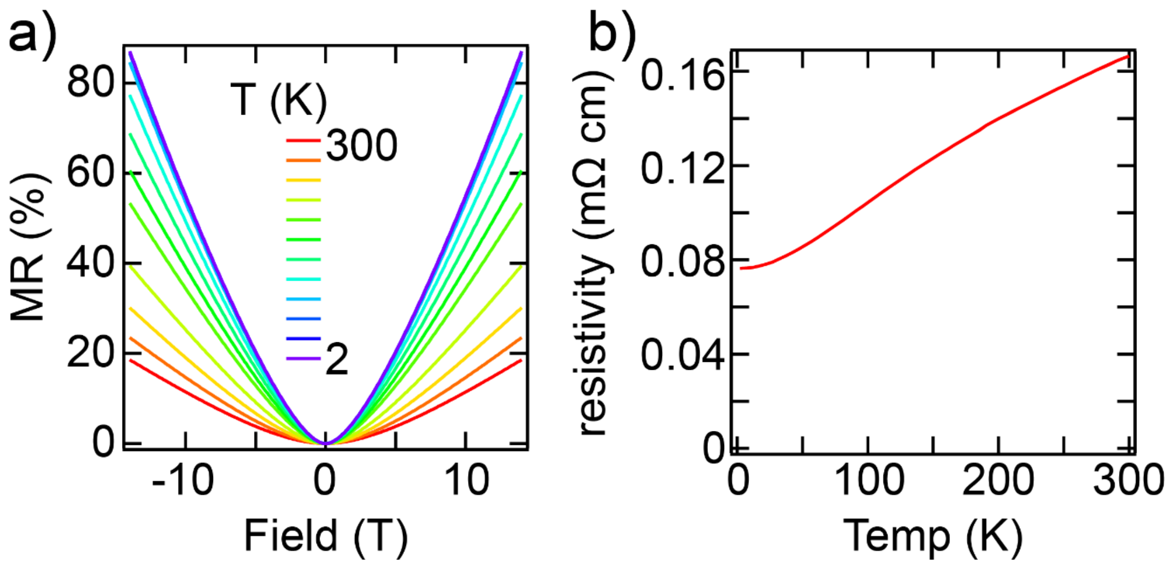

Figure S1 a) Magnetoresistance % as a function of applied magnetic field perpendicular to the sample normal at 2 K. This demonstrates that the films display large magnetoresistance. b) resistivity as a function of temperature displaying metallic behavior down to 2 K.

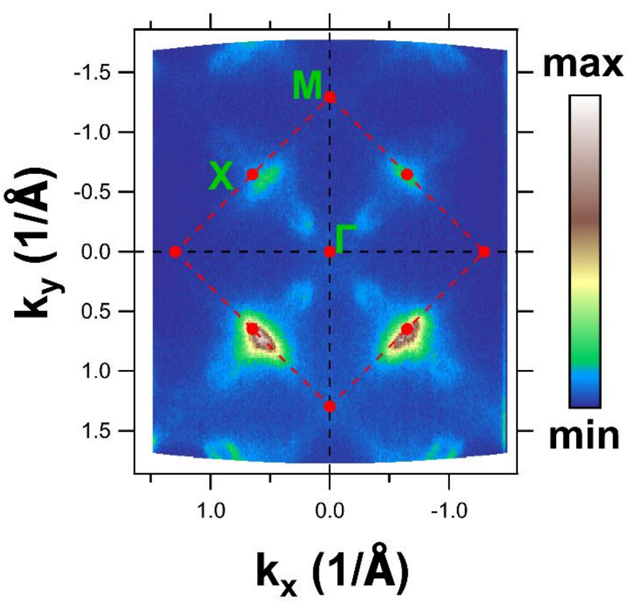

Figure S2. Fermi surface map of a TaAs film showing surface states consistent with measurements of bulk single crystals, hν=90 eV.